A.D. 1855 . . . . . . . . Nº 1318.

# Electric Telegraphs.

**LETTERS PATENT** to Cromwell Fleetwood Varley, of No. 1, Charles Street, Somers Town, St. Pancras, in the County of Middlesex, for the Invention of "IMPROVEMENTS IN ELECTRIC TELEGRAPHS."

Sealed the 26th October 1855, and dated the 9th June 1855.

**PROVISIONAL SPECIFICATION** left by the said Cromwell Fleetwood Varley at the Office of the Commissioners of Patents, with his Petition, on the 9th June 1855.

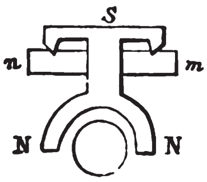
I, CROMWELL FLEETWOOD VARLEY, of No. 1, Charles Street, Somers Town, St. Pancras, Middlesex, do hereby declare the nature of the said Invention for "IMPROVEMENTS IN ELECTRIC TELEGRAPHS" to be as follows:—

1st, a mode of making electro-magnets by which considerably more power is obtain'd from a given amount of wire & electric current, viz., by surrounding the wire coil with iron, nickel, or other magnetic metal, the outer iron giving magnetism of an opposite name to the inner core of iron or other magnetic metal *y*), thus getting double action from the same quantity of wire.

2d, in the application of the above to telegraphic relays, which will complete one or two circuits, using an armature magnetised either permanently or by induction from another larger magnet, so avoiding demagnetisation. The armature is so shaped that it can be actuated by powers resembling that of

the electro-magnet & galvanometer combin'd. The armature in one arrangement is shaped thus:

to embrace a portion of the coil of one of the electro-magnets (No. 1), the outer magnetic coating being divided & a space left for this armature to play between or over. The portion of the magnet which embraces the coil is all of one name, as shewn by letters:




viz., all south or all north. *n*, *m*, is the north end of the large magnet, on which the smaller peculiar-shaped magnet hangs. This magnet would be deflected by the wire coil alone when a current is passing, but by my arrangement I get this power & all the electro-magnetic power of the wire added to it to deflect it. By this arrangement I can have two armatures to the same coil of wire, &c. I mount this armature or magnet on pivots or points or knife edges, so as to lessen friction; but where only one armature is required, as in the Morse's system, a flat disk of iron placed at one end of my electro-magnet (No. 1) will be attracted whenever a current passes; or one portion of the magnet may be made moveable, so as to attract or be attracted by the other portion of the magnet.

3d, in the manufacture of permanent magnets, by which they are render'd more powerful & more permanent. A stream of water is forced past the red hot steel whilst under the influence of an electric helix (with or without the electro-magnetic influence derived, as in No. 1, from the outside of the helix); the steel to be harden'd, taking the place of the core. The hot steel is generally first inserted, & the water immediately forced through the coil. I use also solutions of prussiate of potash for this purpose, it tending to make the surface of the steel more hard. For special purposes mercury at the freezing point or dilute sulphuric acid or other cooling mixtures might be used, producing greater hardness of temper. The great permanence of these magnets, which are used to induce magnetism in the relay armatures, protects the apparatus from the irregular actions arising from atmospheric discharges & changes of temperature.

4th, in the mode of making the translating apparatus, which translate positive or negative currents along the various circuits at the will of the opperator.

Note.—The use of translators is to put extra batteries in play at various points along the line for maintaining direct communication between very distant stations. The two armatures, mention'd in No. 2, close or open local circuits when moved, the one by a positive, the other by a negative current; these local currents pass round the magnets of the printing machine, whose armature, when attracted to mark the paper, at the same time puts relay currents on towards the next station, the one relay current being positive, the other negative; but when all is at rest the line wire is connected up again for transmission in the opposite direction.

The printing machine is an arrangement of wheel-work to move a band of paper at an uniform speed; this paper receives the impressions or marks from two levers actuated by electro-magnets (No. 4). When one armature is attracted, a mark is produced on the right side of the paper slip, & when the other armature is attracted, a mark is produced on the left side.

5. Arrangements by which the residuary magnetism in the electro-magnets is made to cease more rapidly after the cessation of the electric currents, enabling me to work rapidly even when many translators are being used between the communicating stations. To avoid the loss of time arising from the residual magnetism of the magnets, I place a stop, which is struck by the printing lever carrying the armature; when the latter is attracted down, this cuts off the current, & the armature leaves immediately the magnet; but the moment they separate, the current reflows round the coil, & thus the armature is re-attracted, continually vibrating through a very limited space, almost appearing to be still; or the stop is made to cut off a portion of the current round the magnet, so reducing the attractive power of it, thus enabling it to leave quicker. By these means the armature is ready to leave directly the current is taken off. These translators can be made separate from the printing machine when less play is given to the armature & less nicety of adjustment is required. In some cases, where the battery power required is not high, the magnet & armatures No. 2 alone are used for translating currents to more distant stations. This is chiefly for the sake of economy.

6. Arrangements adaptable to both keys & translators, by which the effects of induction in the conducting wires are neutralised. In cases of very long submarine or subterranean wires it is necessary to measure out the quantity of electricity at each contact, so that the wire may not be more highly charged by a long contact than by a short one. This I do at each signal by making contact with a powerful battery during the act of depressing the key (or translator lever), this contact ceasing when the depression is completed, at which moment a portion only of the battery is left in play. By

this means the first contact gives a tone or charge to the wire, which charge the weak battery is intended to maintain at the same strength, so that contacts of long & short duration do not vary the charge of the wire when the signal is completed. This measured charge in the wire is neutralised by contact with a powerful battery during the rising of the key, it ceasing when the key is quite up. Or I use the induction plates of my last Patent to effect a similar purpose in a different way.

7. My alphabet from its simplicity renders communication less liable to be mistaken, & enables it to be transmitted about twice as fast as the Baines' & Morse's, because I use a double instead of a single row of signs; each sign serving for two, according as it is placed on the right or left side of the central division.

8. In modes of making the marks more visible to the eye, by arranging the apparatus so that the indented portion of the paper is forced against a black yielding surface, such as silk or other soft substance, saturated with a soft blacking; secondly, by using a platina wire bent like the letter V, the point being maintain'd red hot by a galvanic current. This point whenever brought in contact with the paper burns in a mark. This latter arrangement offers no perceptible resistance to the regular progression of the paper, as does sometimes the Morse's apparatus, giving erroneous signals; 3d, an ever-pointed pencil may be used.

9. The key-board has two or three keys; those made with two are for overground lines or underground lines of short lengths; those with three have a switch, which switch turns the line wire from the two keys to the single one, which single key produces actions similar to those described in my Patent of Feb^y 1854, enabling the new apparatus to be used like them, with all the advantages of overcoming defective insulation, induction, &c.; so that when the two-key systems which produces different signals by opposite currents is render'd useless by imperfect state of the line, insulations, &c., the switch & third key enables communication to be maintain'd at half speed, viz., equal to that of the present Morse's or Baines' system, the difference of speed arising from the greater complexity of the two latter alphabets. These keys when used for very long underground lines or circuits containing a great many translators have the addition explain'd in No. 6.

These apparatus can be substituted in such portions of a line worked by Morse's system where great business is done, the Morse's system being able to work through my translators as perfectly as their own.

**SPECIFICATION** in pursuance of the conditions of the Letters Patent, filed by the said Cromwell Fleetwood Varley in the Great Seal Patent Office on the 8th December 1855.

**TO ALL TO WHOM THESE PRESENTS SHALL COME**, I, Cromwell Fleetwood Varley, of No. 1, Charles Street, Clarendon Square, Saint Pancras, Middlesex, send greeting.

**WHEREAS** Her most Excellent Majesty Queen Victoria, by Her Letters Patent, bearing date the Ninth day of June, in the year of our Lord One thousand eight hundred and fifty-five, in the eighteenth year of Her reign, did, for Herself, Her heirs and successors, give and grant unto me, the said Cromwell Fleetwood Varley, Her special licence that I, the said Cromwell Fleetwood Varley, my executors, administrators, and assigns, or such others as I, the said Cromwell Fleetwood Varley, my executors, administrators, and assigns, should at any time agree with, and no others, from time to time and at all times thereafter during the term therein expressed, should and lawfully might make, use, exercise, and vend, within the United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, an Invention for "Improvements in Electric Telegraphs," upon the condition (amongst others) that I, the said Cromwell Fleetwood Varley, by an instrument in writing under my hand and seal, should particularly describe and ascertain the nature of the said Invention, and in what manner the same was to be performed, and cause the same to be filed in the Great Seal Patent Office within six calendar months next and immediately after the date of the said Letters Patent.

**NOW KNOW YE**, that I, the said Cromwell Fleetwood Varley, do hereby declare the nature of my said Invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement and accompanying Drawings, that is to say:—

This Invention consists of improvements whereby the speed of transmission is increased, and the distance of direct communication extended, especially in the case of very extended submarine lines. The improved apparatus are less liable to derangement from atmospheric and other causes, are applicable to all kinds of telegraphic conductors, and refer chiefly to systems which are actuated by local circuits.

Fig. 1 represents a relay constructed with the improved electro-magnet; Fig. 2 shews the magnet in section. *a* is a soft iron core, with soft iron ends *f*, *f*, making a reel, on which the covered wire *e*, *e*, is wound; *b*, *b*, are the exterior casing, also of soft iron, which fit on to the ends of the reel, as shown

completed in Fig. 3, held between brass supports *c*, all being clamped together by means of the bolt *d*, which passes through. The whole of the iron inside and outside is magnetized whenever a current of electricity is circulating through the coils of wire *e*, *e*. The iron tube *a*, *a*, is magnetized like an ordinary electro-magnet. The ends *f*, *f*, are the continuations of the poles of *a*, *a*, and are also magnetized by the coils of wire. The casings of iron *b*, *b*, continue on the same poles developing the magnetism of the exterior of the wire coil, rendering the two inner ends of these iron casings the south and north poles of the magnet N. S. The direction of the electric current determines which of the two shall be north, the other being the south pole. The wire coil being thus almost completely encased with soft iron, nearly the whole magnetism of the coil is developed.

Between the poles of the electro-magnet N. S. the moveable piece *g*, Figs. 1, 3, and 4, is suspended from the iron bar *h*, *h*, by means of the two springs *i*, *i*, which keep the bearings *j*, *j*, against the points *k*, *k*, which are made of hardened steel to prevent friction and wear. *l*, *l*, are the two southern ends of compound permanent magnetic bundles, which embrace the iron bar *h*, *h*, Figs. 3, 4, 5, and 6. The piece *h*, *h*, becomes magnetized by contact with the permanent magnets *l*, *l*, and which in its turn imparts magnetism to the moveable piece *g*, whose crescent end exhibits powerful southern magnetism, the whole forming a continuation of the southern pole of the permanent magnetic bundle *l*, *l*. The crescent end, the whole of which is south (or north, as the case may be), and which plays between the tubular poles of the electro-magnet N. S., Figs. 1, 7, &c., has its motion limited by the screws *m*, *n*, fixed on to the slate tablet *o*, *o*, *o*. One of the springs *i*, *i*, Fig. 7, is hooked to the projecting piece *p*; the other spring has a silken cord, by which it is connected to the adjusting axle *q*, *q*, Fig. 5, carrying the dial *r*, *r*. The springs are to cause the piece *g* to press against the stops *m* or *n*, according as the tension of the one is greater than the other, which is effected by winding or unwinding the silken cord on axis *q*, the amount of tension being indicated by the dial *r*, *r*. *s*, *s*, are the ends of the wire wrapped on the core *a*, *a*, and they are connected to the terminals R, E, via the terminals *t*, *t*. The little magnet *u* is to call attention when currents are passing. *v*, *v*, is a piece of brass attached to the slate *o*, *o*, *o*, by which the piece *p*, *p*, &c., and the adjusting dial *q*, *r*, are supported. A current entering from a distant station at R traverses the coils of the electro-magnet *a*, *a*, via the terminals and wires *t*, *s*, *s*, *t*, to E, where it makes its exit. If a positive current enter at R it magnetises the electro-magnet, as shown by S.N., and deflects the piece *g* from *n* to *m* so long as the current is passing. If a negative current enter at R the piece *g* will rest

against *n*, the current acting in the same direction as the springs; but if the springs were so adjusted that the piece *g* rested against *m* instead of *n*, then the negative current would move the piece *g* from *m* to *n*. By this arrangement the crescent piece *g* is acted on, not only by the attractive force of the pole N, but also by the repulsive force of the pole S, added to which it is also acted on by the coil itself independently of the iron. In fact the piece *g* would be deflected if the iron were entirely removed, the latter action being perfectly analogous to that of a galvanometer. I thus obtain great increase of power and rapidity of action.

Where two local circuits are to be actuated, the one by sending a positive the other by a negative current along the line wire, I place a second crescent-ended piece $g^1$, Fig. 8, with its suspending apparatus, &c. under the electro-magnet, the second bar $h^1$, $h^1$, being in connection with the lower or northern end of the permanent magnetic bundle *l*, *l*. The single relay can be very advantageously substituted for my galvanometer relay, patented in 1854.

The local circuit is established whenever the piece *g* touches against *m*. The current from the local battery flows from C, as indicated by the arrows, to the terminal S, which is connected to the piece of iron *p*, *p*, thence to the piece *g* from *g* to *m*, (whenever they touch) from *m* to L, Z, and to the battery again, as indicated by the arrows.

In this sketch a Baine's machine is represented as being worked by the relay. The screws *m* and *n* are pointed with platina, and wedge-shaped pieces of platina are fixed on the piece *g*, by which oblique-acting contacts are obtained, rendering the contact very sure and perfect. When a single relay only is required, I continue the piece *g* all round the electro-magnet. N. B. The piece *g* may be made of hardened steel magnetized. (The electro-magnets described throughout this Specification might be made of nickel or other magnetic metal.)

The permanent magnets *l*, *l*, are made very durable by the apparatus for simultaneously magnetizing and hardening steel bars. Fig. 9 is a hollow helix. *a*, *a*, is a brass tube; *b*, *b*, *b*, *b*, iron discs, forming a bobbin, on which is wrapped covered copper wire *c*, *c*; *d*, *d*, are iron bars (Fig. 10), which are placed outside the coils of wire *c*, *c*, to encase the whole in iron; *e*, *e*, are iron tubes, projecting about $\frac{1}{5}$ or $\frac{1}{6}$ into the helix; *f*, an iron pin; *g*, an iron funnel, for the more easy guidance of the steel bar to the interior of the helix; *h*, a tube connecting the helix with an elevated cistern of water; *i*, *i*, is a small aperture, to empty the helix before putting in another bar, and to carry off leakage. The helix as thus made is plunged into a bath of boiling pitch and wax to saturate and insulate the wire coils; it is ultimately covered with thin

indian-rubber, to effectually prevent water from getting to the insulated wires. When a powerful electrical current is made to pass this helix, the exterior iron, the iron ends *b*, *b*, and the iron tubes *e*, *e*, become powerfully magnetic, forming an electro-magnet, whose poles are developed at N. S; the interior space between N. S. is pervaded by powerful magnetic force.

To make a magnet, pieces of steel are placed in a crucible of animal charcoal, having been previously wetted with a solution of ferrocyanide of potassium. These are heated to a bright red heat, and when sufficiently heated one bar is removed and plunged into the helix around which the current is circulating, and immediately afterwards the cock *j* is opened, when a stream of cold water flows past and hardens the steel bar in a magnetic atmosphere, and also between the poles of a powerful electro-magnet. Magnets so formed are quite hard and powerfully magnetic. The object of the animal charcoal and ferro-prussiate of potassium is to prevent the surface from burning and decarbonization. The magnets when made are placed between the poles of a powerful magnet during the process of brightening or polishing, to prevent the vibration from impairing their magnetism. When very great hardness is required, a freezing mixture or cold mercury might be used.

Fig. 11, Sheet 2, represents the key used for working by means of my translator into the Morse's system; Fig. 12 represents the key at rest; Fig. 13, depressed; Fig. 11, in the act of rising; Fig. 14, an end view. *a*, handle of key, with support *b* and spring *c*, in connection with the line wire; *d*, a stop in connection with the zinc pole of a battery, whose copper pole is connected to the earth; *e*, an overhanging stop in connection with the copper pole of a battery of half the intensity of the other battery; *f* and *g*, two insulated stops; *h*, a contact lever, jointed to *a* by means of the spring cheeks *i*, which clamp it with sufficient friction; *j*, a stop connected to relay; *k*, a spring, which is connected to the earth through a resistance coil *l*; *m*, an insulated post, to keep the spring *k* from touching *a*, excepting when this latter is depressed. The base *n* is made of oiled slate, to insulate the parts and avoid warping. The key being at rest, the line wire is connected to relay through the stop *j*. The contact lever *h* is prevented by the insulated stops *f* and *g* from making contact with the battery poles *d* and *e*. When the handle is depressed, the contact is broken at *j*, *e*, the wire separated from the relay, and the alteration in the angular position of *a* and its contact lever *h* enables the latter to touch *d*, and so connect the wire with the zinc pole of the battery, as shewn in Fig. 13. When the handle is allowed to rise, the friction of the joint *i* carries up the contact lever till it touches *e*, which connects the line with the copper pole of the other battery, as shewn in Fig. 11. This contact

continues while the handle is rising until near the top, when it is broken by the insulated stop *g* previously to the handle again resting on the relay stop *j*. During the time the handle and consequently the line wire is separated from *j* and is in contact with the batteries, it is brought in contact by means of the spring *k* with one end of the resistance coil *l*, the other end of which is in contact with the earth. This coil consists of a great length of fine iron wire, offering great resistance to the passage of electricity, and is employed to equalize the amount of charge which the wire receives for different durations of the time of contact in making dots and dashes. This equalization it effects by its resisting power opposing the passage of electricity when the line wire is but slightly charged, but affording a means of escape for the surplus electricity accumulated during a lengthened contact. These coils are boiled in wax and rosin, to prevent the wire from rusting, and for the sake of better insulation.

## Translators.

By translator I mean the apparatus used for bringing fresh batteries into play to enable correspondence to be maintained direct between stations whose distance apart is too great to admit of connecting the wires into one continuous electrical circuit. Generally speaking, it is not advantageous to attempt to work through more than 200 English miles of the ordinary telegraph wires suspended in the air in one electrical circuit; but by arranging apparatus so that the current through the first electrical circuit shall bring fresh batteries into play, a second distance of 200 miles can be worked through, and so on; but there is a limit to this from the following causes:—1st, the electro-magnets used for putting the second set of batteries into play require a given time for magnetizing; 2ndly, the armature requires also a given amount of time to move towards the magnet to make the contact. 3rdly, an electro-magnet requires more time to magnetize than to demagnetize; thus, in the case of a large electro-magnet, where the time required to magnetize it was 15 seconds, it only required three to demagnatize.

The duration of a dot (•) is not sufficient to magnetize the attracting magnets so fully as the long contact of a dash (—), therefore dots become shortened in a greater ratio than do the dashes, because the armature retires quicker in the former than in the latter case. These actions waste time, and consequently the marks to be printed are shortened at each translating station. Therefore when many translators are in circuit it becomes necessary to write slower, in order that the amount lost at each translation shall not absorb entirely the short marks (or dots). This I have endeavoured to explain more clearly as follows:—

A Circuit containing 4 Translators.

| | |
|---|---|
| 1st station prints his marks slowly, thus | -- — — ——— ——— |
| 2nd station, the translator by losing time prints | -- -- — ——— ——— |
| 3 " " " " " " " | -- -- -- ——— ——— |
| 4 " " " " " " " | - - - ——— ——— |
| 5 " " " " " " " | - - - ——— ——— |
| Last station prints thus | ——— ——— |

In this example the last station cannot read the writing of the first station, because the short marks (technically dots) have been so much reduced that they do not reach thereto; the dashes, however, from their greater length and other causes, scarcely suffer.

In the example given I have not shewn any disturbing action arising from the imperfect isolation of the one wire from the others supported on the same poles, allowing a portion of the electricity from the other wires to enter the circuit in question, and so increase or shorten the dots, according to the direction of the disturbing current. The dashes in this latter case also would not suffer so much as the dots, because of their greater length.

Submarine or subterranean wires insulated from the earth or sea by gutta percha or other non-conducting substances become in action like Leyden vials, the copper wire acting as the interior coating, the gutta percha as the glass jar, and the sea or earth as the exterior coating. If such a wire be connected with a battery, it will receive a powerful charge by induction, similar to that of the Leyden vial, which charge it will retain until the interior and exterior surfaces become connected together through some conducting substance, namely, by the wire being put in connexion with the earth direct, or through the instruments connected with it. The surfaces exposed being very considerable in the case of a wire 150 or 200 miles in length, the charge is so great that the resistance offered by the wire renders the time of charging or discharging appreciable.

If the contact with the battery be so short (as in the case of making a dot) that the wire is not fully charged before the battery contact has ceased, the current at the distant end does not reach its maximum power, and the dot will either not be produced at all, or be very much reduced in length. On the other hand, when a dash (—) is made the contact with the battery is so much longer that the wire becomes fully charged, and the length of time required to effect its discharge lengthens the dash to a considerable extent; therefore, if the relay be adjusted at the distant station to print the dots neatly,

the first dash that is made will give so great a charge to the wire that its effects will not have subsided before the second contact is made; the result of which is, that all the subsequent marks will run together, making a continuous line ——————; marks printed thus — — — ——— — — — — will arrive at the distant station thus — — — ———————, and will consequently be unintelligible.

There are two effects which also interfere with translating through submarine wires. 1st, when the line has been in contact with the battery and becomes charged, it will discharge itself at every place where a channel offers. This charge is much greater at the end of the line next the battery than at the distant one, because of the great resistance of the wire; consequently, when after making a signal the wire of the 2nd circuit is removed from the battery and immediately afterwards connected with the receiving relay proper to that wire (as with ordinary translators), the induced charge of that wire will discharge itself through the coils of the last-named relay to the earth, and from its power will induce so much permanent magnetism therein as to derange it for printing with the weak currents from the distant station. 2ndly, in the case of a translator placed between two submarine circuits the following phenomena would occur:—When a signal was made at one end, a current would be translated into the second circuit, and when the battery contact was broken at this end, the translator would also break contact with the battery it had put on to the second circuit. This second circuit, having become charged like a Leyden jar, would discharge itself through its relay, and so translate back a current to the first station. This first circuit would now become charged, and as soon as the second circuit had become discharged, the charge of the first circuit, by returning through the relay, would translate back again a current through the second circuit. The two relays, &c. would when once started continue in alternate action until the batteries became exhausted; communication under such circumstances would be impossible.

From the foregoing causes, the translating apparatus of Steinheil, as used on the Continent, in conjunction with the Morse machines, is not applicable to submarine wires of greater length than one hundred miles.

My improved translators are arranged to obviate these difficulties in the following cases:—

1st, the extension of my system, patented in 1854, by the means of translation.

2ndly, the translation of my system into that of Morse, and vice versa, enabling both systems to work into each other, as is done in the case of direct communication between London and the Continent via Holland, where the already

existing systems of Morse on the Continent are connected with my system, which is necessary to cross the ocean to England.

3rdly, in cases where the dots are too much reduced to re-establish their proper length, and so enable communication with even many translators to be carried on at a rapid rate.

4thly, translate signals from one submarine circuit to another submarine without inconvenience from the induced charge.

5thly, where the circuit exceeds more than two hundred miles of submarine wire.

1st *Case.—For the Extension of my System patented* 1854.

Figs. 5, 6, and 7, Sheet 1, represent a relay translator, similar to that described in Fig. 1, with the following additions:—1, an armature of soft iron on pivots; 2, 3, & 4, adjusting and contact screws; 5, a spring to hold back the armature 1; 6, a contact spring attached to the armature 1; *m*, *n*, contact adjusting screws, connected respectively with the copper and zinc poles of two batteries whose other poles are in contact with the earth.

The terminals R, E, R 2, L 2, C, S, Z, are connected as follows:—

R and E are the extreme ends of the fine coil wire *e*, *e*, Fig. 1.

L is connected with the armature 1, via the pivots 2, 2, Fig. 7.

R 2 is connected with the contact screw 3.

C is connected with *m*, and Z with *n*; the contact screw 4 is connected to the piece *g*.

S is only used with this translator when it is being used as an ordinary relay, it being connected with the piece *g*; the armature 1 in the latter case being out of circuit.

To translate from one circuit to another, two of these translating relays are used, and are connected as follows:—

No. 1 line is connected to L 2 of No. 2 translator.

No. 2 line „ „ „ L 2 No. 1 „

The terminal R 2 of No. 1 translator is connected to R of No. 2, and R 2 of No. 2 translator is connected to R of No. 1.

When an electric current is passing through No. 1 line, it enters L 2 of No. 2 translator, goes through the armature 1 and the contact screw 3 to R 2, thence to R of No. 1 translator through the coils to E, and then to the earth. If the current passing be a positive one, it will deflect the piece *g* of No. 1 translator against *m*, and at the same time will attract the armature 1, removing it from 3, and making contact with 4; the electric current of No. 1 line thus removed the No. 2 line from connexion with the coils of relay 2, and

put it in contact with *m*, via *g*. A positive current will now flow down the line 2 so long as a current passes through line 1. If the current passing through No. 1 line be a negative one, the same action will take place in translator No. 1, excepting that the piece *g* will be deflected against *n* instead of *m*, and will so translate on a negative current to the distant station. When the current on No. 1 line ceases, the armature 1 will retire and connect up No. 2 line to No. 2 translating relay, and then communication can be carried on in the opposite direction.

N.B.—In my Invention, patented in 1854, a current is continually flowing through the line during transmission of a dispatch, the positive current producing the signals, the negative current the intervals; the latter occupies the wire, and prevents the stray currents from other wires from producing false marks.

2ndly, I also effect a similar purpose with one relay by the addition of the apparatus shown, Fig. 15 and 16, Sheet 2. It consists of two ordinary electro-magnets $a^1$, $a^2$, acting upon the armatures *b* 1, *b* 2, balanced on pivots *c* 1, *c* 2, carrying platina points *d* 1, *e* 1, *d* 2, *e* 2, dipping into mercury cups *f* 1, *g* 1, *f* 2, *g* 2. Line wire 1 enters the terminal L 1, Fig. 17, which is connected to pivot *c* 2, thence to mercury cup *f* 2, via platina point *d* 2; the mercury cup *f* 2 is in contact with R 2 after passing through the coils of *a* 1, as shewn by the red lines. Line wire 2 enters the terminal L 2, is connected to *c* 1, thence by platina point *d* 1, mercury cup *f* 1, and round the coils of *a* 2 to R 2, as shown by the black line. The mercury cups *g* 1, *g* 2, are connected to the terminal S, which is connected, via S of relay, to the piece *g*, as shown by the dotted lines, the terminal R 2 being connected to R of relay.

*Action, &c.*—A current flowing through line 1 enters at L 1, and goes to *c* 2 and to mercury cup *f* 2, via platina point *d* 2, round the coils of the electro-magnet $a^1$, thence to R 2, from R 2 it goes through the coils of the relay to earth; the current passing through the coils of *a* 1 magnetizes it, and attracts the armature *b* 1 to the horizontal position, as shown in Fig. 15, removing the platina point *d* 1 from the mercury cup *f* 1, and plunging platina points *e* 1 into mercury cup *g* 1, thus connecting line 2 with the piece *g* of the relay in place of R 2. The armature *b* being of soft iron is affected in the same manner by positive and negative currents; not so the piece *g* of relay; it being magnetized is deflected to *m* by a positive current and to *n* by a negative, consequently positive or negative currents on line 1 translate respectively positive and negative currents along the line 2.

During the transmission of a dispatch the armature *b* remains horizontal, but the moment the distant switch is turned to "receive," currents cease to

flow; the armature returns to rest as in Fig. 15, 1, and all is ready for transmitting in the opposite direction.

When the switch of my key (patented 1854) is turned over to "send," a negative current flows through the line, bringing one of the armatures of the translator to the horizontal position, which position it maintains so long as the distant switch is turned over. To make a signal, the current is reversed, but not taken off; so long therefore as a current passes, either negative or positive, the armature remains in the horizontal position, connecting the other line wire with the piece *g* of relay; the latter piece *g*, being magnetised, repeats on through line 2 whatever is passing through line 1.

When the switch of sending station is turned back to "receive," the current ceases, and in a second or two the horizontal armature of the translator returns to rest, connecting line 2 to relay again, when an answer can be transmitted. This relay when once adjusted requires almost no attention.

Fig. 18 shows a third plan of relay for my system. *a* is the electro-magnet, wrapped with a double instead of a single copper wire $e$, $e^1$; $f$, $f^1$, are the ends of the double wire; $g$, $g^1$, the magnetized armatures; $m$, $n$, $m^1$, $n^1$, are adjusting and contact screws; $m$ is connected with the copper pole of a battery, and $m^1$ is connected with the zinc pole of a battery; $n$, $n^1$, are insulated stop screws; the ends of the wires $e^1$, $f$, are both connected to the pieces $g$, $g^1$. *h*, a galvanometer, wrapped with two wires *l* 1, *l* 1; *l* 2, *l* 2, the ends of those wires; *o*, *o*, glass resistance tubes containing water to equalise the currents on the lines; *p*, *p*, platina wires dipping into the water in *o*, *o*. The platina wires are in connexion with the line wires, and the water in connection with the earth; by withdrawing or returning the wire the resistance is increased or decreased. The platina wires are attached to a silk cord *q*, *q*, passing over the pully *r*; by turning this pully either of the platina wires can be plunged into the water to equalize the resistance of lines. Line 1 enters at L 1 of galvanometer, and goes through the wire *l* 1, *l* 1, to the terminal R 1, through R 1 of relay, and through its two wires *e*, *e* 1, *f*, *f* 1, to the terminal R 2, which is connected to R 2 of galvanometer; it now circulates again around the galvanometer through the second wire *l* 2, *l* 2, to the terminal L 2, and thence through line 2 to the distant station. When a positive current goes from station 1 to station 3 it passes through station 2; the relay at station 2 deflects the piece *g* against *m*, and so puts on fresh positive power to the line; if a negative current pass through the relay, the piece *g* 2 will be deflected against $m^1$, and will put on fresh negative power.

The battery being applied at the middle of the coils of the relay will split itself equally through the up and down lines, provided they both offer the same

resistance, and as the currents circulate in opposite directions they produce no magnetic power in the relay and no deflection in the galvanometer. If, however, a battery be on at station 1, this equality is disturbed, and more of the intermediate battery's power will go on to station 3. This relay will therefore translate negative and positive currents in either direction without disconnecting the line wire.

The galvanometer is to enable the intermediate station to adjust the resistances. If No. 1 wire offer more resistance than No. 2, depress the platina wire in connexion with No. 1 line, until the galvanometer shows no deflection; when the armature *g* is pressed against *m*, an equilibrium is then obtained, the one current exactly neutralizing the other. This relay can be applied to the needle telegraph. With this kind of relay and overground wires the current is very equal at the distant station in wet or fine weather, because in dry weather the intermediate batteries do almost nothing, but when the loss is great then the intermediate batteries come into play and supply that loss. These relays are also good for very long subterranean circuits, and are placed at intermediate stations. Instead of the tubes for producing partial earth resistance, coils may be used to equalize the resistance of the wires, all the other arrangements being the same.

*Second Case.—Translating from my System into Morse's System, and vice versa.*

Fig. 19 represents the translator as used for transmitting a current, followed by an opposite one as used for working my system into Morse's system, and vice versa, between England, Germany, Belgium, and France, via Holland. This apparatus is arranged to send the double current from the action of a single one, and also to enable the "receiver" to stop the sender during the transmission of a despatch, which is necessary to comply with the system of telegraphing used by the Austro-Gemmanic Union. The system of putting on relay batteries of Steinheil, as added to the Morse machines in Germany, is not suited for working through submarine cables, because of the induced charge, which prevents that system working.

*a*, *b*, *c*, are electro-magnets; L, B, is the local battery which actuates these magnets *d*, *e*, *f*, their respective armatures shown separate Figs. 20, 21; *g*, *h*, *i*, are the upper stops against which the armatures *d*, *e*, *f*, rest by the tension of the springs *h*, Figs. 21 & 22, when the magnets are out of action. The spring *h*, Figs. 21, 22, have dials *c*, *c*, like *r*, Fig. 1, to adjust the tension: *j*, *k*, *l*, are the lower stops, which limit the motion of the armatures when they are attracted by the electro-magnets. The two armatures *e*, *f*, are furnished

(one or both, according to the circumstances of the case, as hereafter explained,) with levers *n*, Fig. 22, carrying at their extremities small spring clicks *o*, engaging the nachet wheels *p*, Figs. 19, 22, insulated on the axle, carrying the fan wheel *q*, dipping in the box of mercury *r*; *s* is a resistance coil, connecting the armature *d* with the earth. When this apparatus is used for translating from my system into Morse's, it is arranged as shown in Diagram No. 1, which represents it with its accessory relays, batteries, &c.

*Example.*—A communication from Hamburg to London, via Amsterdam. The communication passes through the overground line as far as Amsterdam by Morse's single-current system; there it enters the instrument being described, and is there translated into my double-current system, which is necessary to continue the communication through the long submarine cable to London. The single current enters at L 2, proceeds to *e*, thence to *h* and R 2, thence, as shown by the arrows, through its relay to earth. The current circulating through the relay brings the local battery into play, its currents circulating through the electro-magnets *a* and *c* attracting the armatures *d* and *f*. The effect of this motion of the armature *f* is to separate it from the upper stop *i*, and connect it with the lower one *l*, thus separating the submarine line from its relay and connecting it to the armature *d*, which having been simultaneously attracted connects the line with the *z* of the great battery through *j*. When the current from L 2 ceases, the relay breaks the local battery circuit, the armature *d* falls back and connects the submarine line to the copper pole of a smaller battery *c*, transmitting the opposite currents necessary in my system. The armature *f* is made to retire slowly by means of the click, ratchet, and fan wheel *o*, *p*, *q*, dipping into mercury, and thus retaining the line in contact with *l* and *d* for about half a second after the action of the magnet has ceased before re-connecting it with its relay at *i*. The action of the coil *s* is similar to that described in the key, Fig. 11.

When communication is being carried on in the opposite direction, the alternating currents enter at L 1, proceed to *f*, thence to *i* and R 1, thence, as shown by the arrows, through its relay to earth. The local battery circuit now goes through *b*, attracting the armature *e*, removing line from its relay connection at *h*, and connecting it with the great battery at *k*. The Morse machine shown in Diagram can be put in circuit by removing the plug *t*.

Diagram No. 2 shows the same translator adapted for working from one submarine line to another. The difference of this from the one just described is, 1st, that both the armatures *e* and *f* are furnished with clicks and ratchets *n*, *o*, *p*, *q*; 2ndly, the lower stops *k* and *l* are both connected to the armature *d*; 3rdly, the electro-magnet *a* is in circuit with both the electro-magnets *b* and *c*.

This machine transmits alternating currents in both directions, the last current being always a positive one. The return current is also positive, and does not disturb the relays, because they complete the local circuit only when a negative current is passing. The batteries are of unequal power, the same as used with the key already described, Figs. 11 and 12.

*Third Case.—Re-establishing the Length of the Dots.*

The illegibility of the signals, arising from the diminution of the dots (as previously explained), arising from repeated translation, submarine circuits, and other causes, I obviate in the following manner:—

Fig. 24 shows one of my arrangements applied to a Morse's machine. *a*, the writing lever, in connection with No. 2 line wire; *b*, the electro-magnet that moves it; *c*, the stop which connects No. 2 line to its own relay; *d*, the stop which limits the downward motion of the writing lever (or anchor), and is also one pole of the translating battery. When the writing lever is depressed, No. 2 line wire is connected to the battery, and a current is translated on to a more distant station. *e*, the writing point which indents the paper; *f*, *f*, a moveable bar with adjusting weight *g* pivotted into *h*; *i*, platina wire dipping in and out of mercury contained in the cup *j*; *k*, relay contact.

The local circuit is as follows:—The wire from C of local battery after traversing the coils of magnet *b* proceeds to *m*, where it divides, the one going to *l*, the other to *i* through *h*. The wire from *z* of local battery is divided also, one branch going to *k*, the other to *j*, thus giving two points at which the local circuit can be completed. The relay being acted upon as usual by the first line wire, completes the local circuit at *k*, *l*; *b* becomes magnetized, and the lever *a* is attracted down. In doing so it throws the bar *f*, *f*, into the position shown by the dotted lines, which completes the local circuit at *i*, *j*. This contact continues during the time required for the oscillation of the bar *f*, *f*, which is determined by the weight *g*. Should the contract for a dot be so much reduced that the lever *a* be only momentarily depressed thereby, the contact at *i*, *j*, will detain it the proper length of time. The isocronous property of pendulous bodies causes the contact at *i*, *j*, to be of nearly equal deviation under all circumstances. The piece *n* is made of leather or soft material to prevent the bar *f*, *f*, from rebounding. Not only does this correct the defects of the line, but also the irregularities of the sender in making his dots.

By the removal of an ordinary contact plug this piece of mechanism can be

thrown out of circuit. A light spring may be used for the contact *i*, *j*, in place of the mercury cup.

Figs. 25, 26, 27, &c. show another mode of effecting the same purpose by means of clock-work, adapted for translating under various circumstances. The writing lever *a* when depressed discharges the piece *f*, which has two stops of different radius *g* and *h*, which rest against the stud *i*. On the axis *j* is fixed a cam *l* (or cams) to elevate or depress the lever *k*, which is in connection with the line. The time required for the revolution of the cam is regulated by the fly and clock-work. When a current circulates through *b*, the lever *a* is depressed; the stop *g* then passes over the stud *i*, and the piece *f* with the axle and cam runs round until stopped by the pin *h*, resting against the now-depressed stop *i*. Upon the lever *a* rising, the pin *h* passes under the stud *i*, and runs on until stopped in its original position. During this revolution the cam has removed the second line wire from its relay, connected it with and disconnected it from the necessary batteries, and afterwards reconnected it to the relay.

Fig. 31 shows a key, with a similar arrangement attached, to make the dots of not less than the required length at the original station. The magnet *b* is wound as indicated by the dotted lines; therefore when the lever *a* touches the stop *d*, the inner coils are put in short circuit, and so prevents the over magnetization of the iron; this enables a more powerful local battery to be used, and consequently contacts of shorter duration at the relay will suffice; dots that might otherwise have been lost are thus saved.

Fig. 32 shows a mode of actuating a key to transmit a despatch at the original station with perfect regularity. *o*, a long screw, moving at an uniform rate by wheel-work; *p*, a bed with grooves on the inner side of its cheeks, as seen in Fig. 33; *q*, a travelling bar, sliding in the grooves in *p*, *p*, carrying the type TYPE, which are held in their places by the bar *s* and the screws *t*, *t*; *u*, a half nut, fastened under the bar *q*, and engaging the screw *o*; *v*, a V-shaped tooth of hardened steel, fixed to the handle of the key *a*; the other parts of the key are the same as Fig. 11. In transmitting a message the type representing the letters and words are clamped in the bar *q*, which, being placed in the grooves, is driven along at an uniform rate by the action of the screw, the elevation of the type actuating the key with the greatest precision. This type arrangement is applicable to any construction of key. The type are made of hardened steel to prevent wear, and have corresponding Roman letters on one side to facilitate the correction of the despatch when set up. By this means speed and precision are simultaneously obtained.

*4th Case.—Long Submarine Circuits; Submarine Cables of the usual Dimensions of over 200 or 300 Miles Length.*

The length of time required to charge and discharge, in consequence of the very great resistance offered by the wire, is such, that to communicate at a commercial speed it is necessary to measure out the electricity in such a way that the intensity of the charge shall not be greater with a long contact than with a short one. This can be effected by the induction plates of my Patent, dated December 5th, 1854.

Fig. 34 is an arrangement for effecting this purpose, and is represented applied to a Morse's machine for translation, which being explained, it is not necessary to show the key, as its action is precisely similar, it being moved by hand instead of an electro-magnet.

*a*, the working lever (or anchor) in connection with No. 2 wire; *b*, the electro-magnet, actuated by No. 1 line wire; *c*, the upper stop in connection with the relay of No. 2 line wire; *d*, the lower stop in connection with the given pole of a battery evolving a large quantity of electricity, such as Grove's, Smee's, or a large cell, Daniell's battery; *e*, spring in connection with one end of a primary coil, the other end of which is in contact with the earth; *f*, a post supporting the spring *e*; *g* & *h*, adjusting screws to regulate the position of the spring *e*; *i*, the primary coil; *j*, the secondary coil; *k*, the iron core of the induction coil.

*Action.*—When the lever *a* is depressed, the platina piece *l* touches the spring *e*, and forces it down on the stop *d* until it touches the lever *a* at *m*. By this action the No. 2 line wire is first disconnected from its relay at *e*; 2ndly, it is connected at *l* to the primary coil; 3rdly, both the line wire and primary coil are put in contact with the battery at *d*, when the electric current divides, a large portion going round the primary coil, the remainder through the secondary coil to the line wire.

The circulation of the current round the primary coil induces a very powerful but momentary current in the secondary, which gives a charge or tone to the wire. This charge is maintained at the same degree as that given by the secondary current by the current from the battery, which divides itself (as aforesaid) according to the difference between the resistance of the primary coil and line circuit. To balance these exactly, the primary and secondary coils are composed of 12 separately insulated wires, and are connected with two commutators, one of which is shown, Fig. 35; by shifting the plugs of the commutators, the twelve wires composing the primary coil can be connected into one continuous circuit, or into two circuits of half the length, &c., &c., likewise

those of the secondary. By this means the resistance of the primary and secondary coils are adjusted to suit the particular circuit to which they are applied, and when once adjusted never require changing.

When the resistances are properly adjusted, the submarine wire will be charged to the same degree by a short signal (or dot), as by a long one (or dash —), because the charge in each case is the result of the momentary current from the secondary coil, the battery merely maintaining this charge at the same degree. When the signal is completed, and the lever *a* begins to rise, the battery contract is broken; the consequent cessation of the current round the primary coil, causes a powerful current to circulate through the secondary coil in the opposite direction, discharging the wire. This reverse current makes its exit to the earth through the primary coil, which retards it a little, and reduces its intensity, but not its quantity, making it much the same as that of the first current. This apparatus works rapidly through long submarine circuits, and inasmuch as the last charge is always opposite to that required for working my improved relay, its return current does not affect it. This arrangement, therefore, admits of translating from one submarine circuit into another submarine circuit.

When long submarine circuits are worked, the type arrangement, Fig. 32, should always be used. The apparatus for elongating the dots, Figs. 24 to 30, can be applied to this system. I have represented but one induction coil; I prefer several small ones to one large one, because more power is obtained from less wire.

Fig. 26 shows an arrangement for translating currents through submarine wires without the use of the induction coil, the difference between the charges from long and short contacts being sufficiently compensated for in this arrangement for submarine circuits of not more than 200 miles in length.

The cam *m*, Fig. 25, when discharged by the lever *a*, allows the lever *k* to fall upon the stop *c*, connecting the line to the copper pole, where it remains until lifted off by the cam *l*, which, pressing the spring *n* against the upper stop Z, connects the line wire with the zinc pole of a second battery to destroy the charge.

The submarine wire becomes charged to a much higher degree when a dash is made than when a dot, because of the longer contact with the copper pole of battery, and therefore requires a longer contact with the zinc to neutralize the charge. In this machine, when a dot is made in consequence of the quick return of the writing lever *a* to its place of rest, the axle and cam travel uninterruptedly through the entire revolution; but when a dash is made, it is arrested in its course by the pin *h*, Fig. 29, as shown by the dotted lines; and

consequently the latter portion of the revolution which effects the zinc contact occupies a longer space of time, the wheel-work having to start again from a state of rest. The cam *m* and its axle are connected to the relay, and when the lever *k* rests thereon the line wire is connected to it. The portion *o* of the lever *k*, against which the cam *l* presses when elevating it, is insulated from it by ivory. This arrangement elongates the dots, and in a great degree compensates for the inequalities of the charges.

Fig. 27 shows this dot-elongating apparatus applied to the induction coil arrangement for long submarine circuits. The cam *m* is not used, and the cam *l* is of a different shape, as shown in the Figure; the rest has already been fully described.

Submarine cables are rendered defective by the two following causes, which frequently escape detection by the usual galvanic tests:—1st, very long minute pin holes, caused by a drop of water in the warm gutta percha when being laid on the wire; 2ndly, the line is not always in the centre of the gutta percha covering, and though sufficiently covered to withstand the galvanic test it cuts through during the twisting and rough usage the cable undergoes when being submerged, &c. For working through long distances the insulation must be very perfect, in order that the waves of electric force shall reach the distant station. The two above-mentioned faults I test for in the following manner with statical electricity:—

The line to be tested is placed in lengths of a quarter or half a mile in a tub. One end of the line is hermetically sealed, the other is put in contact with the prime conductor of a frictional machine carrying an universal discharger. The machine is now turned, and the line, if perfect, charges like a Leyden jar, until the tension is such that it discharges itself at the universal discharger. If the line will not charge, and yet has stood the galvanic test, the defect can be increased so as to become easy of detection with the galvanomer by the following means:—A large heyden battery is charged to a high degree and then discharged into the wire; the passage of the charge, through the defective spot or spots, will so enlarge it or them as to leave no difficulty in finding and repairing the same.

To prove whether the wire is sufficiently near the centre to be trustworthy, I proceed as in the first instance, allowing one inch of distance between the universal discharger and the prime conductor for every $\frac{1}{8}$ of an inch in thickness of gutta percha covering, because electricity of sufficient tension to pass through $1\frac{3}{4}$ inches of atmospheric air will just burst a hole through $\frac{1}{8}$ of an inch of gutta percha. The minute faults from long pin holes, though not serious at first, are calculated to impair the durability of the cable, because the

passage of powerful currents enlarges them by the small quantity of water becoming heated, and the gutta percha even charred when the current is powerful. These faults will ultimately acquire such magnitude that the wire will be destroyed by electrolytic action. I have known several instances where the wire has been eaten asunder.

In long submarine circuits the intensity of the current has to be increased nearly as the cube of the distance, unless the dimensions of the conducting wire be increased in the proper ratio, by which means any distance can be reached without excessive battery power.

Figs. 36 & 37 shew the printing machine with two writing levers, the one moved when a positive current flows down the line, the second when a negative current. The double relay and treble key board are used with this machine, as hereafter described.

*a*, *a*, are electro-magnets; $a^1$, $a^1$, the second electro-magnet; *b*, one armature; *b*, the second; *c*, the axle of the armature *b*; *d*, the axle of the armature $b^1$, insulated from each other by ivory, as shown at *e*; *f*, the points for marking the paper; *g*, roller round which the paper passes to be marked; *h*, upper roller passing on *g*; *i*, springs to press the rollers together; *j*, the reservoir of paper; *k*, axis to give tension to the springs *l*, *m*; *n*, $n^1$, upper stops; *o*, $o^1$, lower stops to regulate the play of *b*, $b^1$; *p*, a pin projecting from the axis *q*, Fig. 38, carrying the stopping lever *r*; *s*, a barrel with a spiral groove, which runs round until the lever *t* butts against the ends of the groove at *u*, at stops the machine so long as the armatures *b*, $b^1$, are at rest; but if either be attracted, the lever *t* is elevated out of the groove and thrown against the flange *v* by the spring *w*, and the machine will run on until the lever *t* is carried by the action of the spiral to *u*; but if the armatures are depressed before the lever *t* reach *u*, it will fly back again and again to *v* until the armatures cease to work.

Fig. 39 shows one of the armatures removed; it has a spring *x* to insure better contact when translating currents.

*y* is a platina Λ, ignited to a white heat by a battery, to burn holes in the paper instead of simply indenting it. The spirals C, Z, are of copper wire, and are insulated from the bars *f* by pieces of porcelain or glass. These marks are much more visible than simply indented marks. These perforated slips can be used for repeating the despatches to a series of branch stations by an apparatus similar to that used by Baine for printing from perforated paper. Where the points are used, a silk band containing a soft blacking can be run through with the paper, when the indented marks will be black; this band can be used over again many times without renewal.

Fig. 8, Sheet 1, shows the double-action relay; the pieces $g$, $g^1$, are connected with the terminal $c$ of the local battery. The screws $m$, $m^1$, are connected with the terminals $S^1$ and $S^2$. When a positive current flows through the line, the local circuit is completed through $S^1$, and when a negative current flows through the line, the local circuit is completed through $S^2$. The other parts of the relay have all been previously explained.

When the circuit $S^1$ is completed, the right-hand armature $b$ of the printing machine is depressed, and the paper marked on the right-hand side. When circuit $S^2$ is completed, the left-hand armature $b^1$ is depressed, and the paper is marked on the left-hand side. These actions when desired translate on currents to more distant stations. For this purpose No. 2 line wire is connected with the axle $d$; the circuit is continued on through the armature $b^1$ to the upper stop $n^1$, which is connected to the axis $c$ and armature $b$; from $b$ the circuit passes through the upper stop $n$ to the relay of No. 2 line wire. If $b$ be depressed, the line wire is removed from its relay at $n$, and is connected with copper, via $o$. If $b^1$ be depressed, the line wire is also disconnected from its relay at $n^1$ and connected with zinc, via $o^1$, thus translating on to more distant stations similar currents to those by which it was actuated.

## Key Board.

Fig. 40 is a plan; Fig. 41 is a side view, shewing key $a$; Fig. 42 is a side view, showing key $a^2$; Fig. 43 is an end view; Fig. 44 is a front view of switch; Fig. 45 shows the piece $m$. $a$, $a^1$, right and left hand keys; $b$, $b^1$, their sockets; $c$, $c^1$, springs to elevate the handles $a$, $a^1$; $d$, spring contact in connexion with copper pole of battery, the zinc being to earth; $e$, ditto, ditto, in connexion with zinc pole of a battery, the copper being to earth; $f$, $f$, stops to regulate the play of the handles $a$, $a^1$; $g$, central stop connected to relay, and upon which the cross bar $h$ rests, connecting line to relay; $i$, a switch connecting line to $b$, $b^1$, ordinarily via the spring $j$. There is a spring in $i$ which throws over the switch, as shown in Fig. 40 by the dotted lines; and then $a^2$, when at rest depressing the spring $m$, Figs. 40, 45, a negative current circulates down the line. When $a^2$ is depressed, a positive current flows down the line. When the switch is pulled over, the line is connected, via the spring $k$, to the third key $a^2$. The keys $a$ and $a^1$ are to actuate the double writing apparatus; they are used with overground wires and submarine cables of short length. When $a$ is depressed, a positive current flows down the line, via $b$, the switch $i$, and terminal L. When $a^1$ is depressed, a negative current flows down the line, actuating its distant relay and writing apparatus accordingly. The relay is disconnected from the line at $g$ by the

elevation of the cross bar *h*, consequent upon the depression of either handle.

When in the case of overground wires the insulation becomes so bad from damp weather or other causes that this and the ordinary systems will not work, yet can communication at the ordinary speed of Morse's system be carried on by turning over the switch and using the 3rd key, $a^2$, with the Morse's alphabet, in this state the system has all the advantages of the protecting current of my Patent, dated February 1854. The switch by being turned over, as shown by the dotted lines, removes the line wire from the keys *a* and $a^1$, and connects it to $a^2$. In this state, when the key $a^2$ is up, a negative current circulates through the line, and when depressed, a positive current flows to the distant station. In this case the alternate currents enable communication to be maintained when from imperfect insulation and leakage from one wire to the other the ordinary systems fail.

If these machines be used between towns where there is much business, to increase the power of the wires they can also be used for translating in conjunction with the ordinary translators of Steinheil, when only one armature will work. Thus, the introduction of these instruments into a system where the Morse is used will not prevent the ordinary translation from being carried on, as beforehand.

## Claims.

I claim the mode of making electro-magnets as used in my relays, shown in Figs. 1, 2, 3, and 4, &c., in so far as regards the obtaining nearly the whole of the magnetic power evolved by the wire coils, and using the same in conjunction with the deflecting power of the coils of wire, forming the said peculiar shaped electro-magnet for telegraphic relays.

The general arrangement of the relays for completing one or two local circuits, shown in Fig. 8.

The apparatus for and the three modes of extending by translation my system patented in 1854.

The apparatus for translating my system into the Morse's, and vice versa.

The general arrangement of the key for sending alternate currents as used for working my system in conjunction with the Morse's.

The means described for translating from one submarine or subterranean circuit into another.

The use of wheel-work or pendulous bodies to re-establish the length of the short signals lost during translation, enabling long lines containing many translators to be worked with but little loss of speed and with greater certainty.

The general arrangement of double-marking apparatus, described Figs. 36 & 37.

The apparatus for simultaneously hardning and magnetising steel or cast-iron bars.

The triple key board to be used with the foregoing double printing machines.

The use of a marker heated by electricity to perforate the paper, and the use of these perforated slips for re-transmitting the despatch to one or more stations automatically.

The measuring into submarine or subterranean wires definite quantities of electricity, so that the charge of the said wire shall be as nearly as possible the same with long as with short contacts.

The means described in Fig. 26 for reducing the residual magnetism of the electro-magnets used in printing or translating apparatus.

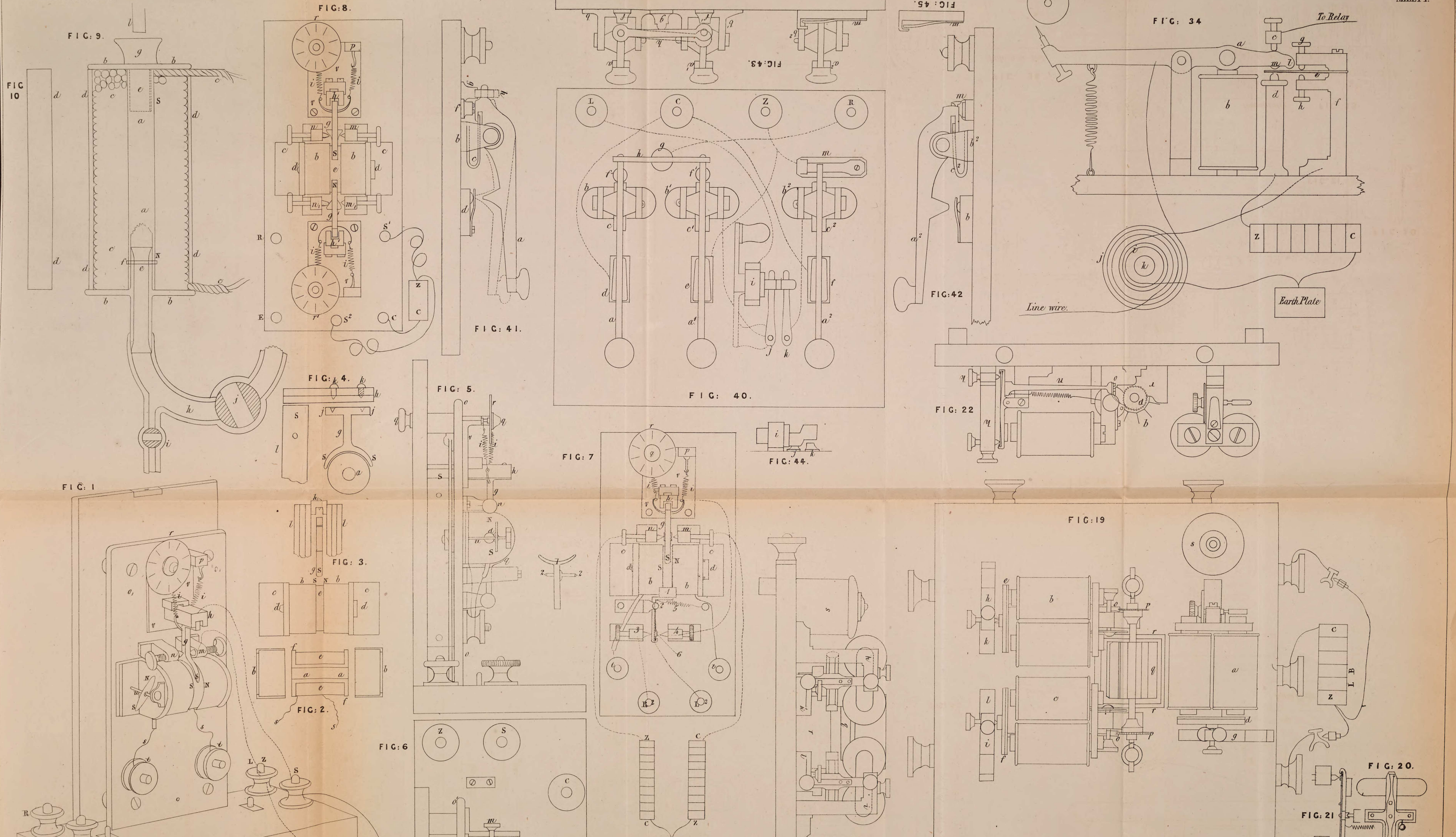
In witness whereof, I, the said Cromwell Fleetwood Varley, have hereunto set my hand and seal, the Eighth day of December, in the year of our Lord One thousand eight hundred and fifty-five.

CROMWELL FLEETWOOD VARLEY. (L.S.)

LONDON:
Printed by George Edward Eyre and William Spottiswoode,
Printers to the Queen's most Excellent Majesty. 1855.

A.D. 1855, June 9. No 1318.
VARLEY'S SPECIFICATION.

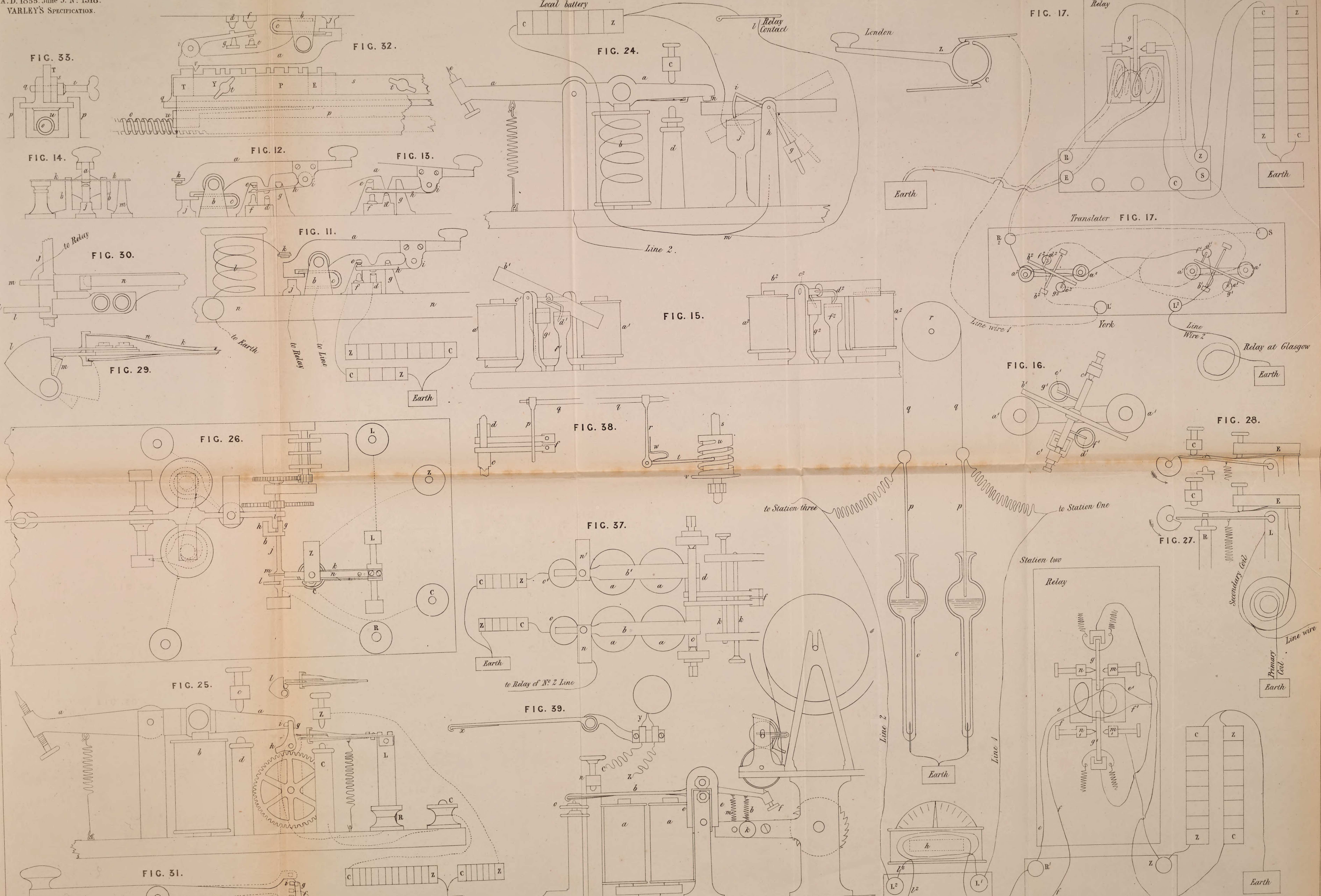
(3 SHEETS)
SHEET 1.




The filed drawing is partly coloured

Drawn on Stone by Malby & Sons.

London: Printed by George Edward Eyre and William Spottiswoode,
Printers to the Queen's most Excellent Majesty. 1855.




The filed drawing is partly colored.

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Printers to the Queen's most Excellent Majesty. 1855.

Drawn on Stone by Malby & Sons.

DIAGRAM 1.

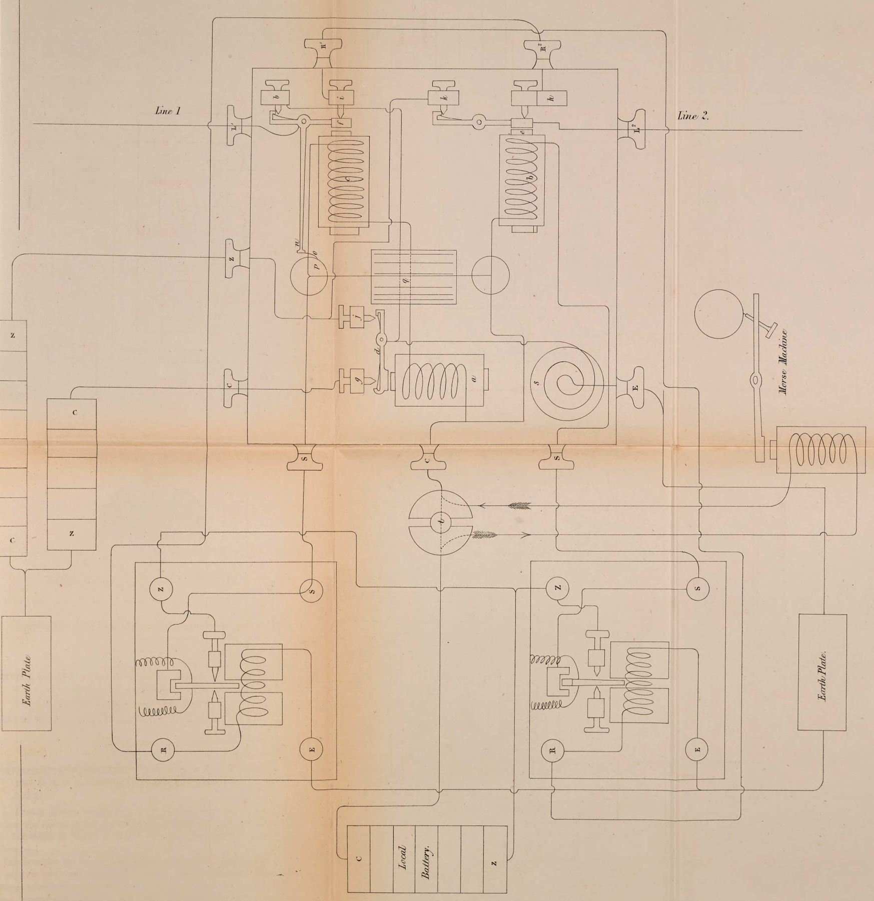
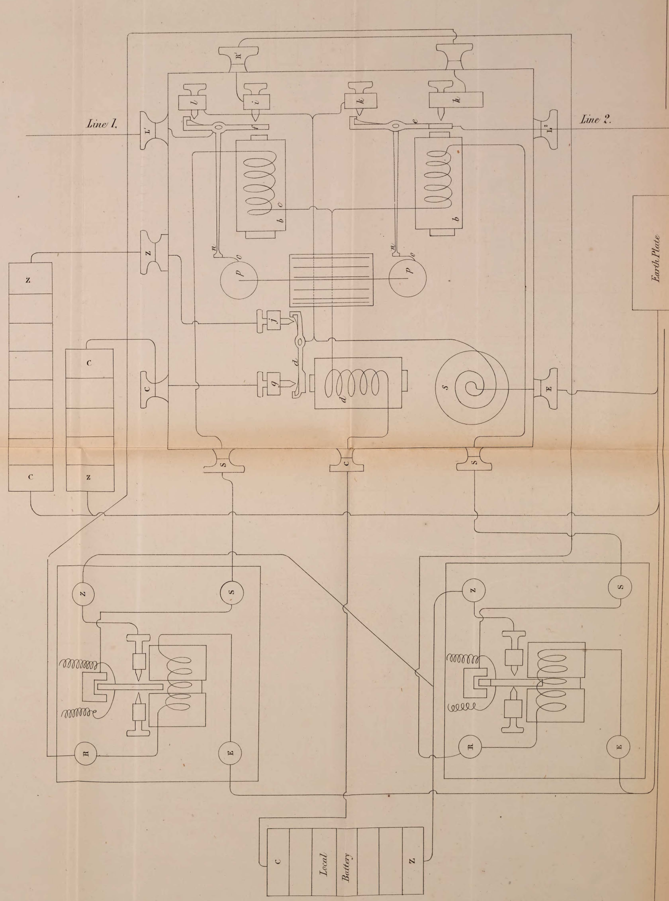



DIAGRAM 2.




*The filed drawing is not colored.*

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